U.S. Army Center for Health Promotion and Preventive Medicine

USCHPPM

NONIONIZING RADIATION PROTECTION STUDY NO. 25-MC-3098-99
OPTICAL RADIATION HAZARD EVALUATION OF THE
INTEVAC, INC., LASER USED IN A TARGET DETECTION SYSTEM
6 JULY 1999

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Readiness Thru Health

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U.S. Army Center for Health Promotion and Preventive Medicine

The lineage of the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) can be traced back over 50 years. This organization began as the U.S. Army Industrial Hygiene Laboratory, established during the industrial buildup for World War II, under the direct supervision of the Army Surgeon General. Its original location was at the Johns Hopkins School of Hygiene and Public Health. Its mission was to conduct occupational health surveys and investigations within the Department of Defense's (DOD's) industrial production base. It was staffed with three personnel and had a limited annual operating budget of three thousand dollars.

Most recently, it became internationally known as the U.S. Army Environmental Hygiene Agency (AEHA). Its mission expanded to support worldwide preventive medicine programs of the Army, DOD, and other Federal agencies as directed by the Army Medical Command or the Office of The Surgeon General, through consultations, support services, investigations, on-site visits, and training.

On 1 August 1994, AEHA was redesignated the U.S. Army Center for Health Promotion and Preventive Medicine with a provisional status and a commanding general officer. On 1 October 1995, the nonprovisional status was approved with a mission of providing preventive medicine and health promotion leadership, direction, and services for America's Army.

The organization's quest has always been one of excellence and the provision of quality service. Today, its goal is to be an established world-class center of excellence for achieving and maintaining a fit, healthy, and ready force. To achieve that end, the CHPPM holds firmly to its values which are steeped in rich military heritage:

★ *Integrity is the foundation*
★ *Excellence is the standard*
★ *Customer satisfaction is the focus*
★ *Its people are the most valued resource*
★ *Continuous quality improvement is the pathway*

This organization stands on the threshold of even greater challenges and responsibilities. It has been reorganized and reengineered to support the Army of the future. The CHPPM now has three direct support activities located in Fort Meade, Maryland; Fort McPherson, Georgia; and Fitzsimons Army Medical Center, Aurora, Colorado; to provide responsive regional health promotion and preventive medicine support across the U.S. There are also two CHPPM overseas commands in Landstuhl, Germany and Camp Zama, Japan who contribute to the success of CHPPM's increasing global mission. As CHPPM moves into the 21st Century, new programs relating to fitness, health promotion, wellness, and disease surveillance are being added. As always, CHPPM stands firm in its commitment to Army readiness. It is an organization proud of its fine history, yet equally excited about its challenging future.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	8 July 1999	Study, 6 July 1999

4. TITLE AND SUBTITLE
Nonionizing Radiation Protection Study No. 25-MC-3098-99, Optical Radiation Hazard Evaluation of the Intevac, Inc., Laser used in a Target Detection System

5. FUNDING NUMBERS

6. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NUMBER
25-MC-3098-99

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
The purpose of this study is to evaluate the potential health hazards associated with the optical radiation emitted by the Intefac, Inc., laser used in a target detection system and to make recommendations designed to eliminate the exposure of personnel to potentially hazardous optical radiation produced by this device.

14. SUBJECT TERMS

15. NUMBER OF PAGES
10

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

DEPARTMENT OF THE ARMY
U.S. ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
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REPLY TO
ATTENTION OF

EXECUTIVE SUMMARY
NONIONIZING RADIATION PROTECTION STUDY NO. 25-MC-3098-99
OPTICAL RADIATION HAZARD EVALUATION OF THE
INTEVAC, INC., LASER USED IN A TARGET DETECTION SYSTEM
6 JULY 1999

1. PURPOSE. To evaluate the potential health hazards associated with the optical radiation emitted by the Intevac, Inc., laser used in a target detection system and to make recommendations designed to eliminate the exposure of personnel to potentially hazardous optical radiation produced by this device.

2. CONCLUSIONS. The Intevac, Inc., laser used in a target detection system emits optical radiation that exceeds the current protection standards. The potential for causing eye injury may be eliminated provided that the operators are informed of the potential hazards and take appropriate precautions.

3. RECOMMENDATIONS. Detailed recommendations are contained in paragraph 8 of the subject report. It is recommended that a safety SOP for maintenance personnel be prepared and posted, personnel wear appropriate eye protection out to the nominal ocular hazard distances (NOHDs), and the laser system either comply with 21 CFR 1040 or the alternate safety design requirements contained in MIL-STD 1425A, should this laser system enter into development phase.

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NONIONIZING RADIATION PROTECTION STUDY NO. 25-MC-3098-99
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INTEVAC, Inc., LASER USED IN A TARGET DETECTION SYSTEM
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1. REFERENCES.

a. Title 21, Code of Federal Regulations, Subchapter J, Part 1040, Laser Products.

b. DODI 6055.11, Protection of DOD Personnel from Exposure to Radiofrequency Radiation and Military Exempt Lasers, 21 February 1995, with enclosure, FDA Exemption 76EL-01DOD, 29 July 1976.

c. TB MED 524, 20 June 1985, Control of Hazards to Health from Laser Radiation.

d. American National Standards Institute (ANSI), Safe Use of Lasers, American National Standards Institute Z-136.1-1993, Orlando, FL, Laser Institute of America.

e. MIL-STD-1425A, 30 August 1991, Safety Design Requirements for Military Lasers and Associated Support Equipment.

2. AUTHORITY.

a. Telephone conversation between Mr. Terry Lyon, this office and Dr. Nick Barr, Night Vision Electro-Optics Laboratory (NVEOL), 29 June 1999.

b. Memorandum, AMSEL-RD-NV-ST-LT, subject: Request for Support, 30 June 1999.

3. PURPOSE. To evaluate the potential health hazards associated with the optical radiation emitted by the Intevac, Inc., laser used in a target detection system and to make recommendations designed to eliminate the exposure of personnel to potentially hazardous optical radiation produced by this device.

4. GENERAL.

a. Background. The laser system contained a commercial product manufactured by Big Sky, model ULTRA CFR Nd:YAG Laser System, to which Intevac, Inc., added laser output optics for beam collimation. The entire system was intended to be used as a target illuminator and with other electro-optics components could be used for active target detection. Commercial laser products, like the Intevac, Inc., laser, which are sold in the United States, must comply with the laser performance standards in 21 CFR 1040. The laser was classified from a hazard standpoint by Big Sky to be a Class IV laser product. Laboratory and field measurements were conducted at Aberdeen Proving Ground, Maryland on 6 July. This system consisted of two modules in a "one-of-a-kind" setup: a laser head which was attached to an Optical Parametric Oscillator (OPO) module to generate relatively safe 1574 nm radiation from potentially harmful 1064 and 532 nm laser output radiations and a power supply with an integrated cooler. The complete system was intended to be used for demonstration purposes only and was not currently under development.

b. Instrumentation.

(1) Ophir Laser Power Meter, Model Nova, SN 47327, with detectors, Model PE-50, SN 49078, and PE-25, SN 43534.

(2) Viewers: U.S. Army NIR viewer, Model S4-43/PAS-6; FJW Industries NIR viewer for 1.5 μm; and Kodak IR phosphor card.

(3) EG&G Near Infrared detector, Model 580-23A, SN 274.

(4) Palentronix Radiometer Indicator, Model AR582F, SN 96F24106.

(5) Filters: three each BG-36, 3 mm thick; three each KG-5, 3 mm thick; neutral density filter set D; and water filter.

(6) Laser beam analyser system with Electrophysics Micronviewer.

(7) Laser beam divergence kit consisting of 1 and 2 m lenses and a set of calibrated circular apertures, thermal paper, and optical comparitor.

c. Abbreviations. A table of radiometric abbreviations used in this report is given in the appendix.

5. FINDINGS.

a. System Description. The system employs a KTP frequency-doubled neodymium

yittrium aluminum garnet (Nd:YAG) laser to pump an optical parametric oscillator (OPO), producing a final output wavelength of 1574 nm. The laser emerges from a variable divergence transmitter telescope which can be adjusted for a near collimated beam.

b. Hazard Classification. The Big Sky laser was classified from an optical hazards standpoint as a Class 4 laser product according to ANSI Z136.1 (reference 1d). Without the output optics supplied by Intevac, Inc.,, the laser output would contain multiple wavelengths and appropriate control measures for a Class 4 laser need be followed as outlined in references 1c, 1d, and 1e. However, the laser system as evaluated contained filtered output optics which provide the following output parameters:

(1) Wavelength: primary wavelength of 1574 nm (reported), leakage 532 nm emission were below measurement limits and visual limits, and some 1064 nm leakage emission was barely detectable.

(2) Initial Beam Diameter: 4.8 cm clear exit aperture, and 1.5 cm measured to 1/e-peak-radiant-exposure-points.

(3) Pulsewidth: approximately 6 ns (reported).

(4) Pulse Repetition Frequency: selectable from 1, 2, 5, 10, and 20 Hz (reported and confirmed 20 Hz).

(5) Effective Beam Divergence: 1.5 mrad minimum (reported) and 1.0 mrad worst-case measured when collimated to 1/e-peak-radiant-exposure-points to an effective circular beam.

(6) Radiant Energy/Pulse at 1574 nm: 6 mJ/pulse reported and 7.4 mJ/pulse measured at 20 Hz and 7.9 mJ/pulse at 1 Hz.

(7) Radiant Energy/Pulse at 1574 nm through an Aperture:

(a) 4.8 mJ/pulse measured at 1.4 m through a 25 mm circular aperture (for magnifying optics).

(b) 2.1 mJ/pulse measured at 20 cm through a 7 mm circular aperture and 0.77 mJ/pulse at 1.4 m measured through a 7 mm circular aperture (for magnifying optics)

(c) 0.65 mJ/pulse measured at 20 cm through a 3.5 mm circular aperture (for eye and skin).

(d) 47 μJ/pulse measured at 20 cm through a 1 mm circular aperture (for

eye for single pulse).

(8) Radiant Energy/Pulse at 1064 nm: < 0.2 μJ/pulse measured.

c. Warning Labels. Three warning labels and a Laser Aperture label were present upon the laser head. Two of the labels read: CAUTION - LASER RADIATION WHEN OPEN, AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION, HIGH VOLTAGE HAZARD MAY EXIST WITH COVER REMOVED. The third label read: VISIBLE AND INVISIBLE LASER RADIATION, AVOID EYE AND SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION, 1574 nm 4 nsec 15 mJ, 1064 nm 6 nsec 75 mJ, 532 nm 6 nsec 45 mJ, 355 nm 5 nsec 20 mJ, 266 nm 5 nsec 15 mJ, CLASS 4 LASER PRODUCT COMPLIES WITH 21 CFR 1040.10/EN 60825-1:1994.

d. Identification Label. An identification label from Big Sky was located on the rear side of the power supply and integrated cooler module which read: MODEL ULTRA, MANUFACTURED: MARCH 1998, PART NUMBER: 17009100, SERIAL NUMBER: 98031901. A small label which read: INTEVAC, Inc., 183939, was also present. Intevac, Inc., might be viewed as a laser manufacturer having modified the original Big Sky laser system. Laser manufacturers are required to provide an identification label on their products. This label is normally permanently attached to the laser housing and contains the full name and address of the manufacturer, the laser model, and the place, month, and year of manufacture.

e. Remote Control Connector. A remote control interlock was present on the rear panel of the power supply and integrated cooler module which was intended for use during maintenance or service, to interlock the system to the entrance door switches in the maintenance or service area.

f. Alternative Safety Features. Should the Intevac, Inc., laser system be employed into a military application it could conceivably employ the alternate safety design features provided in MIL-STD 1425A. The following paragraphs describe some of the key alternative requirements.

(1) Exemption Label. No exemption label was attached to the laser as outlined in reference 1e, paragraph 4.2.2. Apparently no FDA exemption from the laser performance standard had been sought for military use of the laser system. Should the exemption be utilized for this device, a letter of certification from a government procurement office should be sent to the laser manufacturer certifying their product as exempt from any requirements in the FDA radiation safety performance standards. Should this device be certified as exempt a permanent label would be required on the laser housing with the following statement:

CAUTION

This electronic product has been exempted from FDA radiation safety performance standards prescribed in Title 21, Code of Federal Regulations, Chapter I, Subchapter J, pursuant to Exemption No. 76EL-01 DOD issued 26 July 1976. This product should not be used without adequate protective devices or procedures.

(2) Unintentional Output and Extraneous Radiation. No secondary beams were observed to depart from the primary beam and into potentially uncontrolled areas. Negligible levels of 532 nm radiation and 1064 nm laser radiation were coaxial with the primary 1570 nm laser beam.

(3) Key Control. The power supply and integrated cooler module did employ a key control switch to secure the device.

(4) Laser Fire Switch. Besides employing a "key control" switch for laser activation, a "RUN-STOP" switch activated the laser, and a panic style button could be used to shut the laser off in an emergency.

(5) Exit Beam Shutter. A mechanical and opaque exit beam shutter was located on the laser head which could be used to dump the raw laser beam and thereby prevent any output emissions when the control was mechanically rotated 90 degrees.

(6) Emission Indicators. A small LED on the laser power and integrated cooler module was used to inform the laser operator that the system was actually emitting laser radiation. Also, an audible indication could be heard from the sound of the repetitious rap of the flashlamps and their power supply.

6. DISCUSSION.

a. FDA Requirements. Laser products normally must comply with the Radiation Safety Performance Standards issued by the Food and Drug Administration (FDA), Center for Devices and Radiological Health (CDRH), in Title 21, Code of Federal Regulations, Subchapter J, Part 1040.10 and 1040.11. The FDA does not certify laser product compliance with these laws. This standard requires laser system manufacturers to include certain safety design features in laser products sold in the United States. Such products may be required to incorporate safety features such as warning lights, warning labels, housing interlocks, etc.

b. Military Laser Exemption. In 1976, the FDA Commissioner exempted certain military laser products from the provisions of the FDA Standard (FDA Exemption No. 76 EL-01

DOD), e.g. where warning indications would compromise camouflage. This exemption is only for military lasers used for actual combat or combat training or those classified in the interest of national security. Government contracting officials must certify that these laser products can employ this exemption by preparing a letter to the manufacturer for a specific product. MIL-STD-1425A, Safety Design Requirements for Military Lasers and Associated Support Equipment, provides alternative requirements for the safe design of military exempt laser products. The military exemption issued to all DOD requires manufacturers to meet all requirements of 21 CFR 1040 for these systems except where compliance would hinder mission fulfillment during actual combat or combat training operations or when the laser product is classified in the interest of national security.

c. Exposure Criteria.

(1) 1574 nm Emission. The single pulse, accidental and staring exposure Maximum Permissible Exposures (MPEs) and Accessible Emission Limits (AELs) at 1574 nm are given below:

	Single Pulse Exposure	10 s Exposure
MPE ocular	1.0 J/cm^2/pulse	5.0 mJ/cm^2/pulse
AEL ocular	7.9 mJ/pulse @ 1 mm	0.48 mJ/pulse @ 3.5 mm
MPE skin	10 mJ/cm^2/pulse	0.1 W/cm^2
AEL skin	0.96 mJ/pulse @ 3.5 mm	9.6 mW @ 3.5 mm

d. Hazards from the Direct Beam.

(1) The NOHDs at 1574 nm for this laser are summarized below. The NOHD(M) with magnifying optics was calculated assuming 7x50 binoculars.

	NOHD	NOHD(M)
Single Pulse Exposure	0 m	0 m
Staring Exposure (10 s)	0 m	80 m

(2) Eye Protection. Laser protective eyewear with ODs 1.0 for optically aided viewing at 1574 nm would be sufficient to protect against the laser at all distances, under normal circumstances.

(3) Skin Exposure. Normally the unfocused laser beam does not pose a potential for skin injury. However a focused beam could slightly exceed conservative skin exposure standards in the region of the focused beam. Simple controls would help preclude potential injury although the degree and extent of this hazard is difficult to determine without knowing specific parameters of the particular set up. During laser usage where the beam is focussed, skin should be covered by a close weave fabric. Hand protection should also be used, especially

when working around a focused beam.

(4) Fire Hazard. The output laser radiation, either unexpanded or focused, does not present a significant fire hazard.

(5) Hazard Classification. The laser was classified from a hazard standpoint as Class 3a by ANSI Z136.1. However, opening the laser housing could expose personnel, such as maintenance personnel, to Class 4 levels.

7. CONCLUSION. The Intevac, Inc., laser system used in a target detection system emits optical radiation that exceeds the current protection standards. The potential for causing eye injury may be eliminated provided that the operators are informed of the potential hazards and take appropriate precautions.

8. RECOMMENDATIONS.

a. Prepare and post a safe operating procedure (SOP) for laser maintenance personnel upon the Intevac, Inc., laser which instructs maintenance personnel to take appropriate safety precautions when the laser output optics are removed as for maintenance. This would include wearing laser protective eyewear which affords protection at all emission wavelengths [AR 40-5, paragraph 5-38b(3) and paragraph 9-9c(5), and TB MED 524, paragraph 3-23].

b. Ensure that persons using binoculars within the NOHD(M) of the laser wear laser eye protection with an OD of at least 1.0 at 1574 nm [NOHD(M) of 80 m] [AR 40-5, paragraph 9-9c(5), with TB MED 524, paragraph 3-23].

c. Ensure that, if exposure to the focused or unexpanded laser beam is possible, persons wear laser eye protection with an OD of at least 1.2 at 1574 nm [AR 40-5, paragraph 9-9c(5), with TB MED 524, paragraph 3-23].

d. Should the Intevac, Inc., laser used in a target detection system enter into development, ensure that the laser system either complies with 21 CFR 1040 or the alternate safety design requirements contained in MIL-STD 1425A where compliance with 21 CFR 1040 would hinder mission fulfillment during actual combat or combat training operations or when the laser product is classified in the interest of national security. Government contracting officials

must certify that a laser product can employ this exemption by preparing a letter to the manufacturer for a specific product. If the laser system has been certified as exempt from 21 CFR 1040, then FDA requires an exemption label as depicted in paragraph 5(1) be permanently attached to the laser housing. [AR 40-5, paragraph 9-9c(2) and FDA Exemption No. 76 EL-01DOD].

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Appendix

Useful Radiometric Units[1,2]

Term	Symbol	Definition	Unit and abbreviation
Radiant Energy	Q	Energy emitted, transferred, or received in the form of radiation	joule (J)
Radiant Power	Φ	Radiant Energy per unit time	watt (W) defined as J/s
Radiant Exposure (Dose in Photobiology)	H	Energy per unit area incident upon a given surface	joules per square centimeter ($J \cdot cm^{-2}$)
Irradiance or Radiant Flux Density (Dose Rate in Photobiology)	E	Power per unit area incident upon a given surface	watts per square centimeter ($W \cdot cm^{-2}$)
Integrated Radiant Intensity	I_P	Radiant Energy emitted by a source per unit solid angle	joules per steradian ($J \cdot sr^{-1}$)
Radiant Intensity	I	Radiant Power emitted by a source per unit solid angle	watts per steradian ($W \cdot sr^{-1}$)
Integrated Radiance	L_P	Radiant Energy emitted by a source per unit solid angle per source area	joules per steradian per square centimeter ($J \cdot sr^{-1} \cdot cm^{-2}$)
Radiance[3]	L	Radiant Power emitted by a source per unit solid angle per source area	watts per steradian per square centimeter ($W \cdot sr^{-1} \cdot cm^{-2}$)
Optical Density	OD	A logarithmic expression for the attenuation produced by a medium $OD = -\log_{10}\left(\frac{\Phi_O}{\Phi_L}\right)$	unitless Φ_O is the incident power; Φ_L is the transmitted power

1. The units may be altered to refer to narrow spectral bands in which the term is preceded by the word *spectral* and the unit is then per wavelength interval and the symbol has a subscript λ. For example, spectral irradiance E_λ has units of $W \cdot m^{-2} \cdot m^{-1}$ or more often, $W \cdot cm^{-2} \cdot nm^{-1}$.

2. While the meter is the preferred unit of length, the centimeter is still the most commonly used unit of length for many of the terms below and the nm or μm are most commonly used to express wavelength.

3. At the source $L = \frac{dI}{dA \bullet \cos\theta}$ and at a receptor $L = \frac{dE}{d\Omega \bullet \cos\theta}$.